

THE CAM SHELL: AN INNOVATIVE DESIGN WITH MATERIALS AND MANUFACTURING

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Abstract

Most of the personal audio and video recording devices currently sold on the open market all require hands to operate. Little consideration was given to designing a hands-free unit. Such a system once designed and made available to the public could greatly benefit mobile police officers, bicyclists, adventurers, street and dirt motorcyclists, horseback riders and many others. With a few design changes water sports and skiing activities could be another large area of application. The cam shell is an innovative design in which an audio and video recording device (such as palm camcorder) is housed in a body-mounted protection system. This system is based on the concept of viewing and recording at the same time. A view cam is attached to a helmet wired to a recording unit encased in a transparent body-mounted protection system. The helmet can also be controlled by remote. The operator will have full control in recording everything. However, the recording unit will be operated completely hands-free. This project will address the design considerations and their effects on material selection and manufacturing. It will enhance the understanding of the structure of materials, and how the structure affects the behavior of the material, and the role that processing play in linking the relationship between structure and properties. A systematic approach to design feasibility study, cost analysis and problem solving will also be discussed.

Key Words: Polymers, Acrylics, Polycarbonates, Thermoforming Process, Computer-Aided Design (CAD), Design for Manufacturability (DFM), Design for Assembly (DFA), Rapid Prototyping (RP), Concurrent Engineering, Quality Function Deployment (QFD), Ashby Diagrams

Objective: To provide an environment with a realistic understanding of the design process.
To apply the structure-property-processing relationship to a real product design.

Equipment and Materials:

1. Acrylic sheet (3.175 mm thick, 609.6 mm x 609.6 mm)
2. Polycarbonate (4.76 mm thick, 609.6 mm x 609.6 mm)
3. Thermoforming machine
4. Strip heater
5. Double stick adhesive tape
6. Scissors
7. Exactor knife
8. Super glue
9. Velcro (50.8 mm wide and 914.4 mm long, 2 pieces)
10. Allen head screws (31.75 mm long, 6.35 mm in diameter, 2 pieces)
11. Acrylic plastic hinges (2 pieces)
12. Polyurethane foam (12.7 mm thick)

Introduction

In our technological society, engineering design plays an important role in creating innovative products and services, improving existing commercial machine performance, promoting new product development, encouraging business entrepreneurship, and enhancing the quality of life for our society. To teach the design process and to enhance the learning opportunity and experience in product/process design for our students, a product design laboratory project in conjunction with thermoforming process was developed. Students were guided through the entire design process beginning with the design concept, material selection to a fabricated product using a correct manufacturing process. The structure-property-processing relationship was then evaluated upon the completion of the project.

Product design process can be broadly categorized into three major areas: computer-aided engineering design (CAD), design for manufacturability and assembly (DFM/A), and rapid prototyping fabrication (RP). Each area requires computer hardware, unique software, and certain equipment to perform specific functions for developing a new product. Before the product design process initiates, the problem statement must be identified first. Then, a product development plan will be generated. Engineering specifications and initial concepts for the design will be developed, concept feasibility evaluation will be performed, and final concept selection will be refined. Based on the selected design concept, a product design development and evaluation will then be performed. These may include material and geometric configuration selections for the design (Ashby diagrams), relevant engineering analyses, and design optimization tasks. Rapid prototype fabrication will be implemented to expedite and enhance the design process. (Due to time constraints, this step was not performed in this project.) Tests will be performed on the design prototype. An iterative process will be used to finalize the product design. Cost evaluation and manufacturing specifications will also be considered. Final as-built documentation will be made for the product.

Product Design

• Establish a Design Procedure with Key Elements

At this stage, a basic design concept and product cycle for a product design process will have to be developed in class. This includes needs assessments, product specifications (employing concurrent engineering and quality function deployment practices), functional requirements, concept evaluations and decision-making. Tasks associated with the product and process design will be identified and grouped so that they can be planned, scheduled, and processed easily. Students will be asked to use computer software such as Auto CAD and Microsoft Project 2000 to aid in their design. Besides the Thomas Register database and Internet access, supplementary design handbooks (Dieter's engineering design book and ASM handbooks) will be provided for this lab project.

• Learn how to do Process Planning

Lab instruction materials related to process planning will be provided. In this lab activity, students will learn how to use computer software to help manage multiple tasks. First, students will learn the functions and requirements for Microsoft Project 2000. Then they will design and list all possible manufacturing processes related to the product they have just created. All variables affecting the production process will be implemented in the planning. They include cost factors, human resources, time management, priority scheduling, equipment allocation, etc. Finally, a network logic diagram will have to be constructed using the same software.

Students will have to apply the concepts of the critical-path method (CPM) and program evaluation review technique (PERT) to determine the most feasible and efficient way to conduct manufacturing processes. Priorities will be assigned according to the critical paths.

• **Develop a Laboratory Procedure for Manufacturing and Assembly**

In order to effectively design a product for manufacturability, one must clearly understand the principles and methodologies involved in manufacturing. Among conventional manufacturing practice in a manufacturing plant, process engineering is the utmost important. In the process engineering area, designers have to realize the advantages and disadvantages of each process chosen for a designed product. In general, there are eight major categories associated with processes: (1) casting processes, (2) deformation processes, (3) machining processes, (4) polymer processing, (5) powder processing, (6) joining processing, (7) surface treatment processes, and (8) assembly processes.

The factors that influence the selection of a process for a design involve the manufacturing cost and the cost associated with product life cycle, the quantity of parts to be made, the complexity of the product and material, quality of the part, and availability of material, manufacturing lead-time, and delivery schedule. The designers have to go through a systematic approximation for each factor. The total weighted number will help the designer find the most feasible way for a process. Using this approach, an algorithm embedded with the thoughts for manufacturability and assembly will be established in the software. Once a design is created, a designer can enter the dimensions of the product and any necessary requirements for a final product (such as packaging, vibration, and surface conditions). A systematic approach can be executed, and an optimal condition for manufacturing and assembly can be established.

At this stage, a polymer thermoforming process will be introduced to the class. The viscoelastic behavior of a polymer along with the material orientation will be analyzed in order to expedite the experiment. Temperature and time factors will be studied against each selected plastic material. Some statistical functions and defect controls and reporting can also be implemented in the various lab activities. Specific manufacturing and assembly processes will be recommended for optimal design consideration. In addition, students will also be able to analyze the operational planning procedure for production of the product design to determine the most feasible and efficient way to conduct manufacturing processes. Priorities will be assigned according to the critical paths.

Material Selection

Professor Ashby of University of Cambridge, UK, has generated many useful materials selection charts that can compare a large number of materials at the concept design phase. A common practice in a design phase is to minimize weight or cost. Lines of constant slope are drawn on the diagrams. Depending on the product requirements (geometry and loading conditions) lines of different slope will apply. In this project the product requirements such as lightweight, impact strength, damping resistance, optical clarity, and cost factors are determined to be the key factors for material selection. Polycarbonate is chosen due to its high impact resistance and acceptable cost. Two sample charts are selected and are shown below. Figure 2 is a chart comparing specific modulus to specific strength. Figure 3 is a chart comparing strength with cost per volume.

Experimental Procedure

A pattern, as shown in Figure 1, was drawn based on the original design. A polycarbonate sheet (4.76 mm thick) was cut to size (355.6 mm x 558.8 mm). Edges were filed to provide a smooth surface. Four corners of the plastic sheet were drilled and milled to secure the attachment of the Velcro straps. A strip heater was utilized to form a bend in order to fit the body curvature.

A thermoformer was turned on, and the temperature was set to 200°C. The polycarbonate sheet was placed under a radiant heater. The heater was quickly removed once the plastic sheet was in a pliable state. The plastic sheet was then sandwiched between a pre-designed square shaped yoke and a platen. Air pressure was turned on slowly until movements of the plastic sheet began. Only one atmospheric pressure (14.7 psi) was needed to blow form a spherical (dome) shape of the polycarbonate sheet. Too much pressure would force the plastic into a bubble shape that, if too rapid, the plastic would burst. The air pressure was held until the polycarbonate sheet was cooled. A free air blown part was then created. A back sheet (acrylic) combined with the molded part was joined together using double-stick tape. Velcro straps were sewn to the four attachment points. The plastic hinges were bonded to the surface of the back plate using the super glue. The fabrication of the cam shell was then completed. The final integration part of this cam shell design was to add a camera to a recorder (kept in the cam shell). The cost analysis, shown in Table 1, was performed based on the total cost for one part (prototype) and for 300 parts (a mass-produced environment). Cost reduction was listed for future manufacturing consideration.

Table 1. Cost Analysis

Item	Prototype Cost (1 unit)	Production Cost (300 units)
Blow Mold	\$300.00	\$300.00
Foam	\$8.00 ea.	\$4.35/ea. x 300 = \$1,305.00
Hinges	\$3.00 ea. x 2 = \$6.00	\$1.25 ea. x 300 = \$375.00
Hardware	\$0.28 ea.	\$21.00 lot
Adhesives	\$19.25	\$38.50 lot
Labor	6 hrs @\$75.00 = \$450.00/ person	40 hrs @\$75.00 = \$3,000/person
Polycarbonate sheet	\$24.00 ea.	N/A
Polycarbonate sheet 4 x 8 enough for 10 pcs.	N/A	\$117.00/sheet x 30 = \$3,510 for 300 units
Acrylic sheet	\$8.00 ea.	N/A
Acrylic sheet 4 x 8 enough for 15 pcs.	N/A	\$42.00/sheet x 20 = \$840 for 300 units
Total costs	\$815.53	\$9389.00 for 300 units or \$31.29 per unit

Conclusions

The prototype development of the cam shell from the design concept to product completion was found to be educational and enjoyable. The product was completed with some satisfaction. Students learned the concept of design process by employing a system approach. The relationships among structure, property, and processing were studied using the Ashby

diagrams. By evaluating the finished prototype, students can relate their design to future product improvement. During the design process the cost analysis and the material performance were evaluated at the same time. Although physically working the product development was a beneficial experience in understanding development processes. However, the real benefit would be to automate production providing consistent quality while maximizing profits and material performance.

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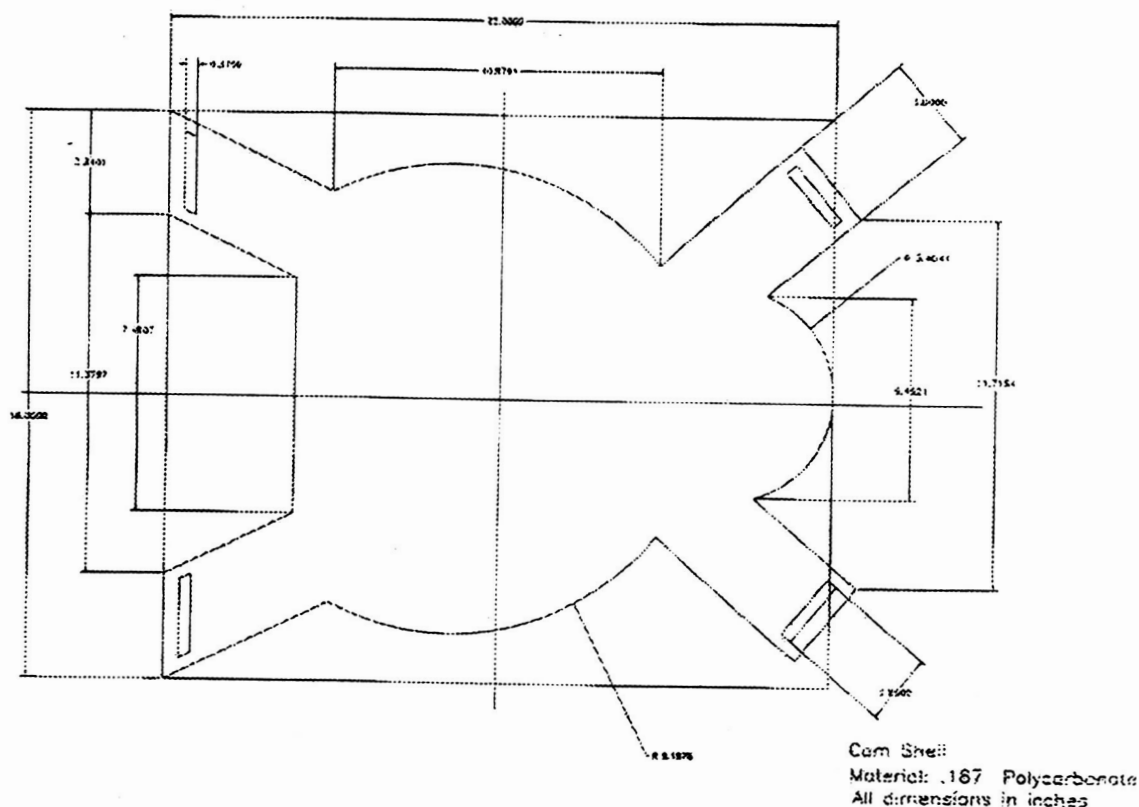


Figure 1. The Dimensions of the Cam Shell Design

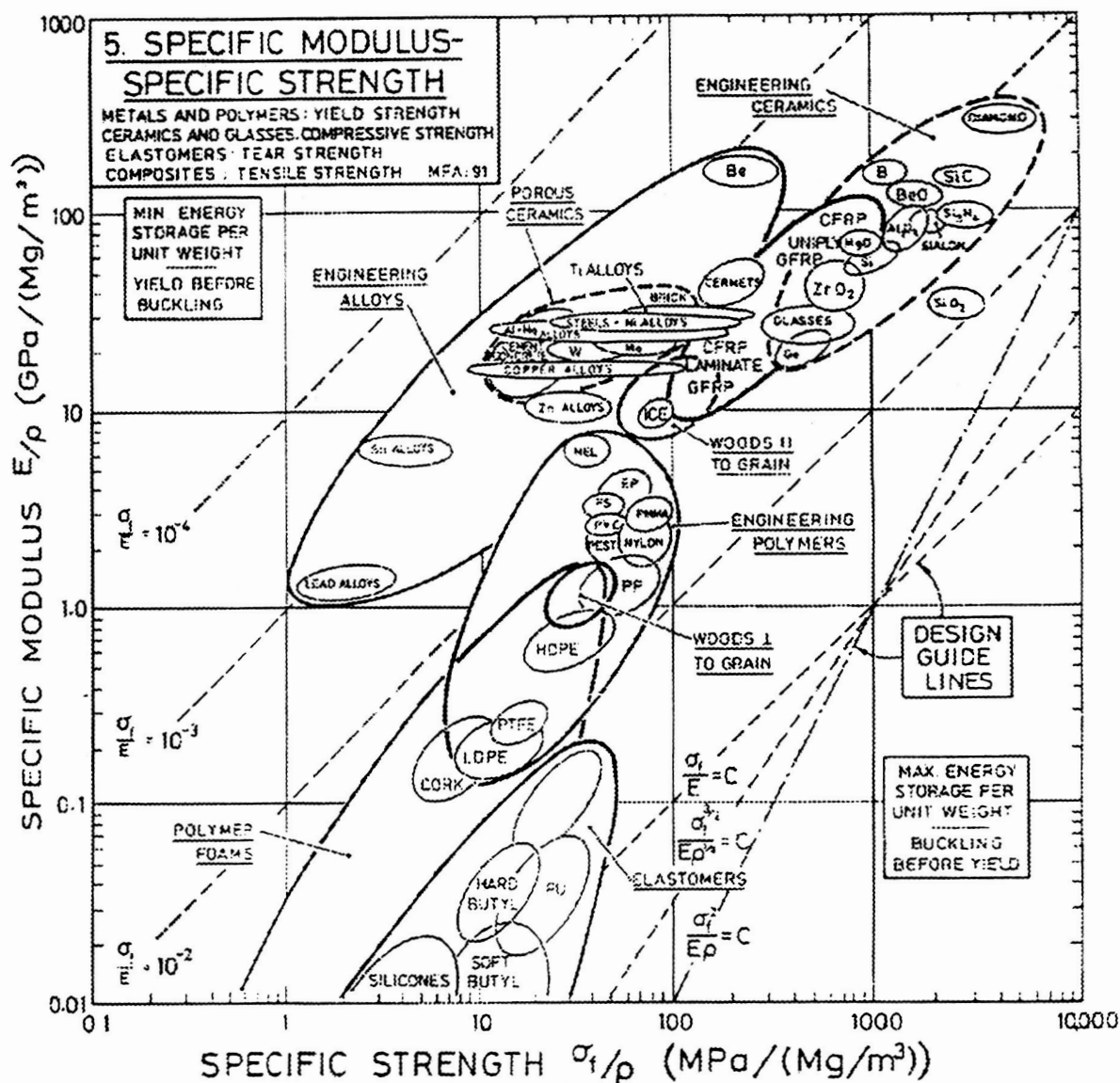


Figure 2. Ashby Diagram: Specific Modulus versus Specific Strength

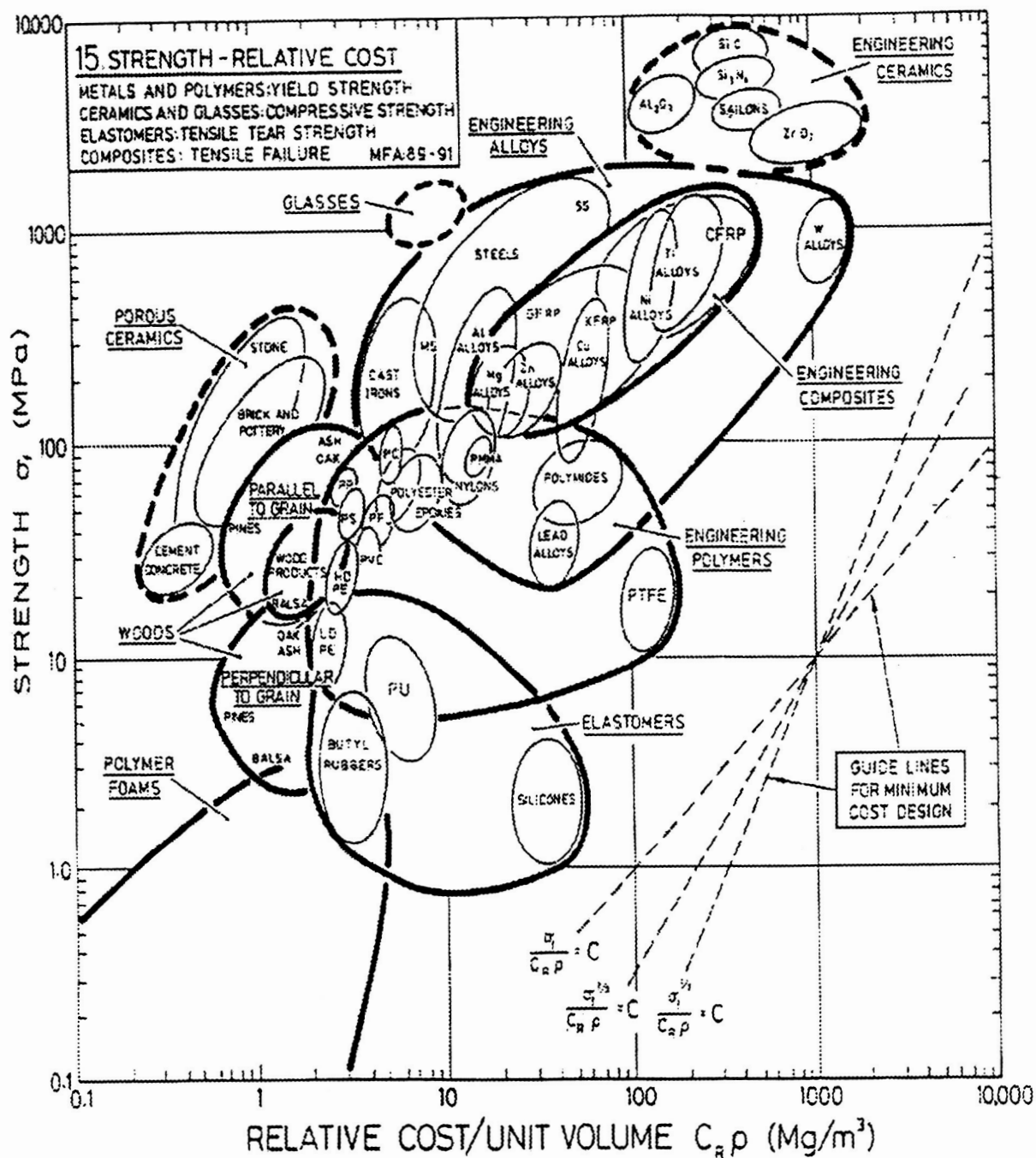


Figure 3. Ashby Diagram: Strength versus Relative Cost per Unit Volume

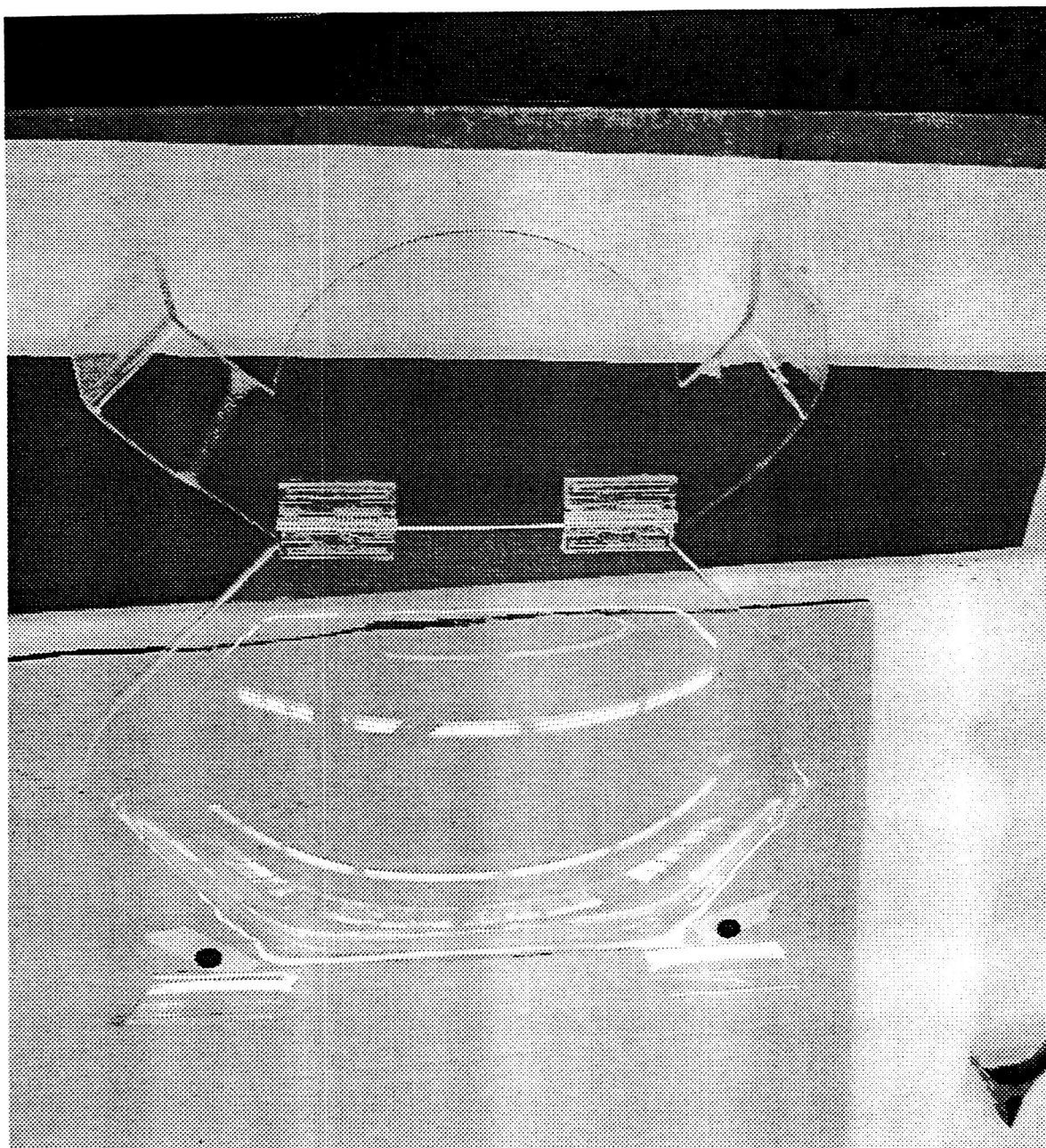


Figure 4. Semi-finished Product

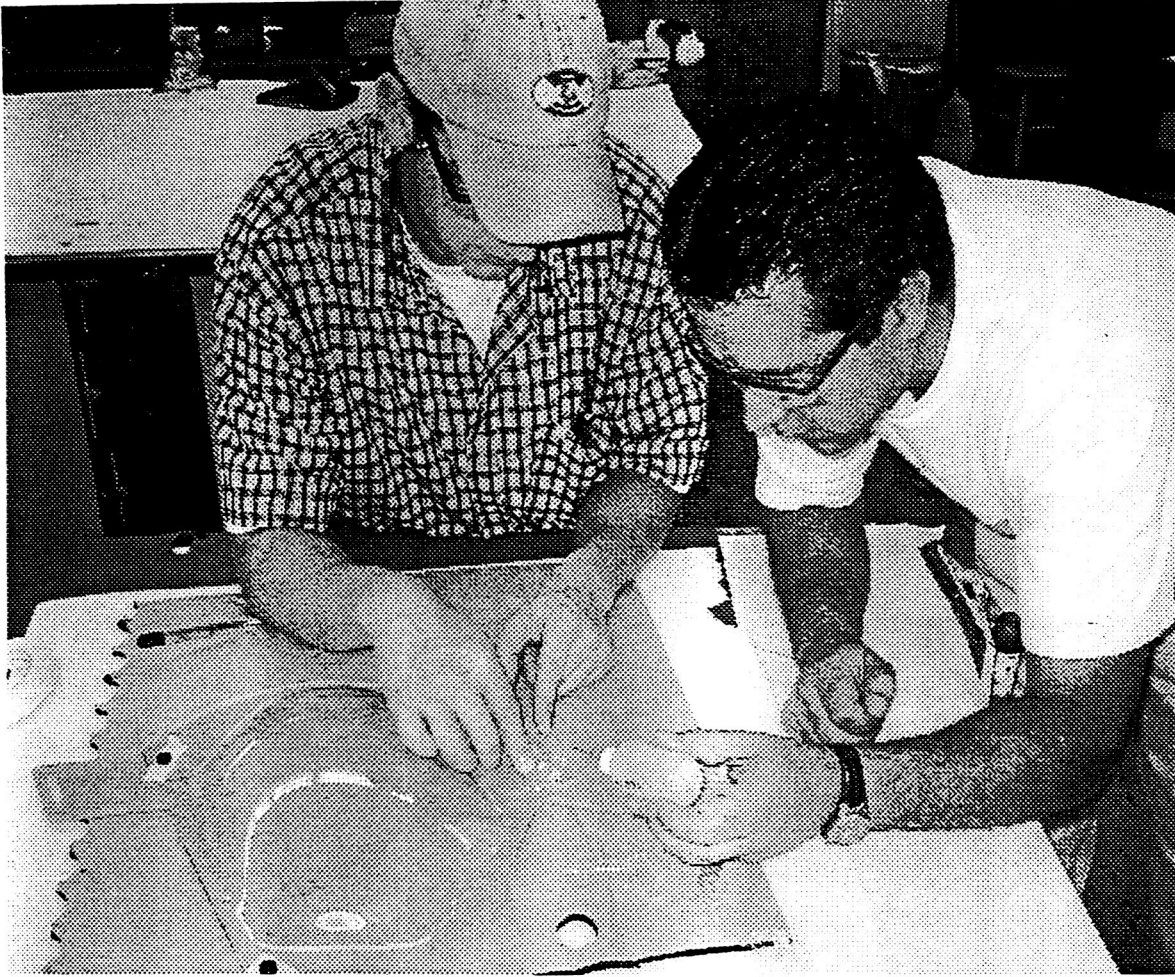


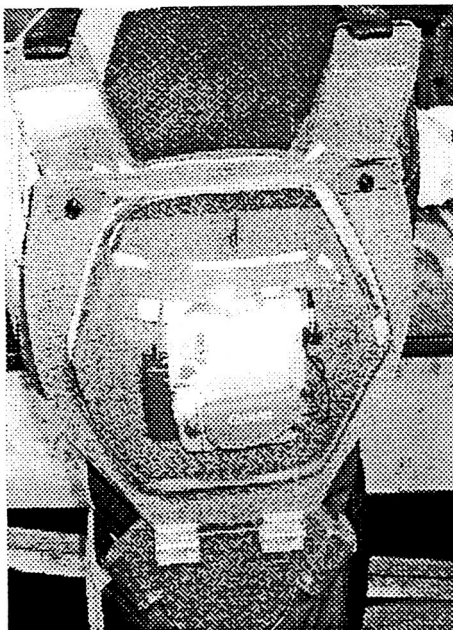
Figure 5. Acrylic Hinges Were Chemically Adhered to the Molded Part



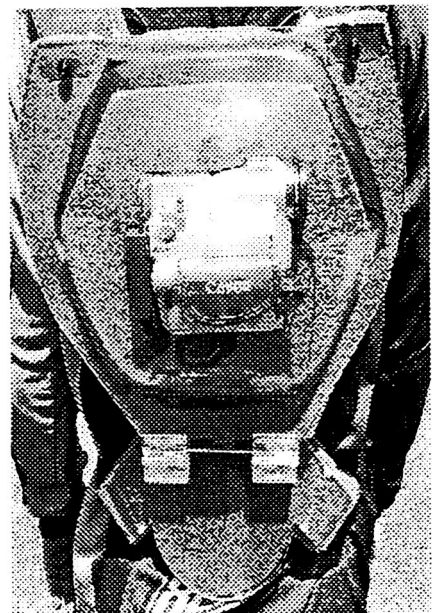
Figure 6. Stand Back View



Figure 7. Stand Front View



(a)



(b)

Figure 8. Rear Close Up Views (a) and (b)